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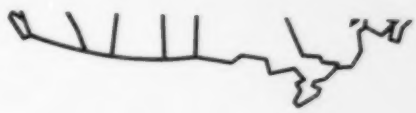
Population levels and biological mortality factors of Spruce Budworm in Balsam Fir stands in Newfoundland during 1982

E. J. Dobesberger and K. P. Lim

Information Report N-X-218
Newfoundland Forest Research Centre



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POPULATION LEVELS AND BIOLOGICAL MORTALITY FACTORS OF SPRUCE BUDWORM, CHORISTONEURA FUMIFERANA (CLEM.), IN BALSAM FIR, ABIES BALSAMEA (L.) MILL., STANDS IN NEWFOUNDLAND DURING 1982.

by E.J. Dobesberger and K.P. Lim

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ABSTRACT

Population dynamics of the spruce budworm, Choristoneura fumiferana (Clem.), were studied in seven balsam fir, Abies balsamea (L.) Mill., stands across insular Newfoundland. The density of spruce budworm, the degree of aggregation, the degree of parasitism and the incidence of disease for the early larval (2nd to 4th) instars, late larval (5th to 6th) instars, and pupal stages are summarized for each stand.

Population levels were low in all stands with less than five budworm per mid-crown branch tip in the early larval stage. Most sample frequency distributions could be adequately described by the negative binomial distribution, but not by the Poisson distribution for the early and late larval stages. Pupal counts were too low to fit either distribution.

The incidence of biological mortality factors varied considerably between stands and between successive life stages of the spruce budworm. Parasites and a microsporidian pathogen, Nosema fumiferana (Thom.), however, occurred on larval and pupal stages. Fungal diseases were found only in larval stages.

RÉSUMÉ

La dynamique des populations de la tordeuse des bourgeons de l'épinette, Choristoneura fumiferana (Clem.), a été étudiée dans sept peuplements de sapin baumier Abies balsamea (L.) Mill., dans l'île de Terre-Neuve. La densité des tordeuses, le degré d'agrégation, le degré de parasitisme et l'incidence des maladies chez les premiers stades larvaires (du 2^{e} au 4^{e}) et les derniers (le 5^{e} et le 6^{e}) et chez les chrysalides sont exposés brièvement pour chaque peuplement.

Les populations étaient faibles dans tous les peuplements; aux premiers stades elles n'excédaient guère cinq larves par extrémité de branche prélevée en milieu de cime. Dans la plupart des case, la distribution de fréquences pouvait obéir à la loi binomiale négative, mais non à celle de Poisson pour ce qui est des premiers et derniers stades larvaires. Le nombre de chrysalides était trop faible pour obéir à ces deux lois.

L'incidence des facteurs biologiques de mortalité a considérablement varié d'un peuplement à l'autre et d'un stade biologique à l'autre. Les parasites et les mycoses ont été très efficaces contre les premiers stades larvaires. À l'opposé, l'incidence de Nosema fumiferana (Thom.) était plus faible, mais s'est exercée à tous les stades du cycle évolutif de l'hôte.

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POPULATION LEVELS AND BIOLOGICAL MORTALITY FACTORS OF SPRUCE BUDWORM, CHORISTONEURA FUMIFERANA (CLEM.), IN BALSAM FIR, ABIES BALSAMEA (L.) MILL., STANDS IN NEWFOUNDLAND DURING 1982

by

E.J. Dobesberger and K.P. Lim

INTRODUCTION

Population dynamics of the spruce budworm, Choristoneura fumiferana (Clem.), deals with the quantification of this forest pest and with factors that affect its abundance in both space and time. An understanding of the processes which influence the dynamics of the spruce budworm is fundamental in any attempt to manage or implement control over the pest population.

The history of the spruce budworm outbreak in Newfoundland that began in 1971 is comprehensively reviewed by Hudak and Raske (1981). Seasonal development of the budworm on the Island generally lags two to three weeks behind populations found in the Maritime Provinces of Canada (Crummey and Otvos 1980).

Current data suggests a decline of population levels over most of Newfoundland (Raske et al. 1982), with only a few scattered pockets of infested stands limited to western Newfoundland that encompass a total area of about 165 000 ha. Although much knowledge has accumulated about the dynamics of the spruce budworm at high or epidemic density levels (Morris 1963), there is limited information on the dynamics of this forest pest at low or endemic population levels.

This report summarizes the dynamics of several spruce budworm populations across insular Newfoundland in 1982. The density of spruce budworm, the degree of aggregation, the degree of parasitism and the incidence of disease for the early larval (2nd to 4th instars), late larval (5th to 6th instars), and pupal stages are summarized for each stand. The spatial distributions at each developmental stage are described in terms of either the Poisson or negative binomial distributions (Southwood 1978).

MATERIALS AND METHODS

Location and Establishment of Research Plots

A preliminary sample for overwintering, second instar larvae was carried out to identify stands suitable for the establishment of research plots to study the population dynamics of the spruce budworm. A total of 21 balsam fir stands were sampled across Newfoundland in April 1982. One, 45 cm mid-crown branch tip was taken from each of nine balsam fir trees at each sampling location. Larval density was determined by washing with sodium hydroxide (NaOH) as outlined by Miller *et al.* (1971).

Seven balsam fir stands were later selected to study the population dynamics of the spruce budworm (Fig. 1). Three stands were situated in western Newfoundland near the communities of Robinsons, Gallants, and Pasadena. Another three were located in central Newfoundland near Gullbridge Mine Road by Badger, near Baie Verte, and near Lake Ambrose by Millertown. The remaining stand was located near Jamestown on the Bonavista Peninsula in eastern Newfoundland.

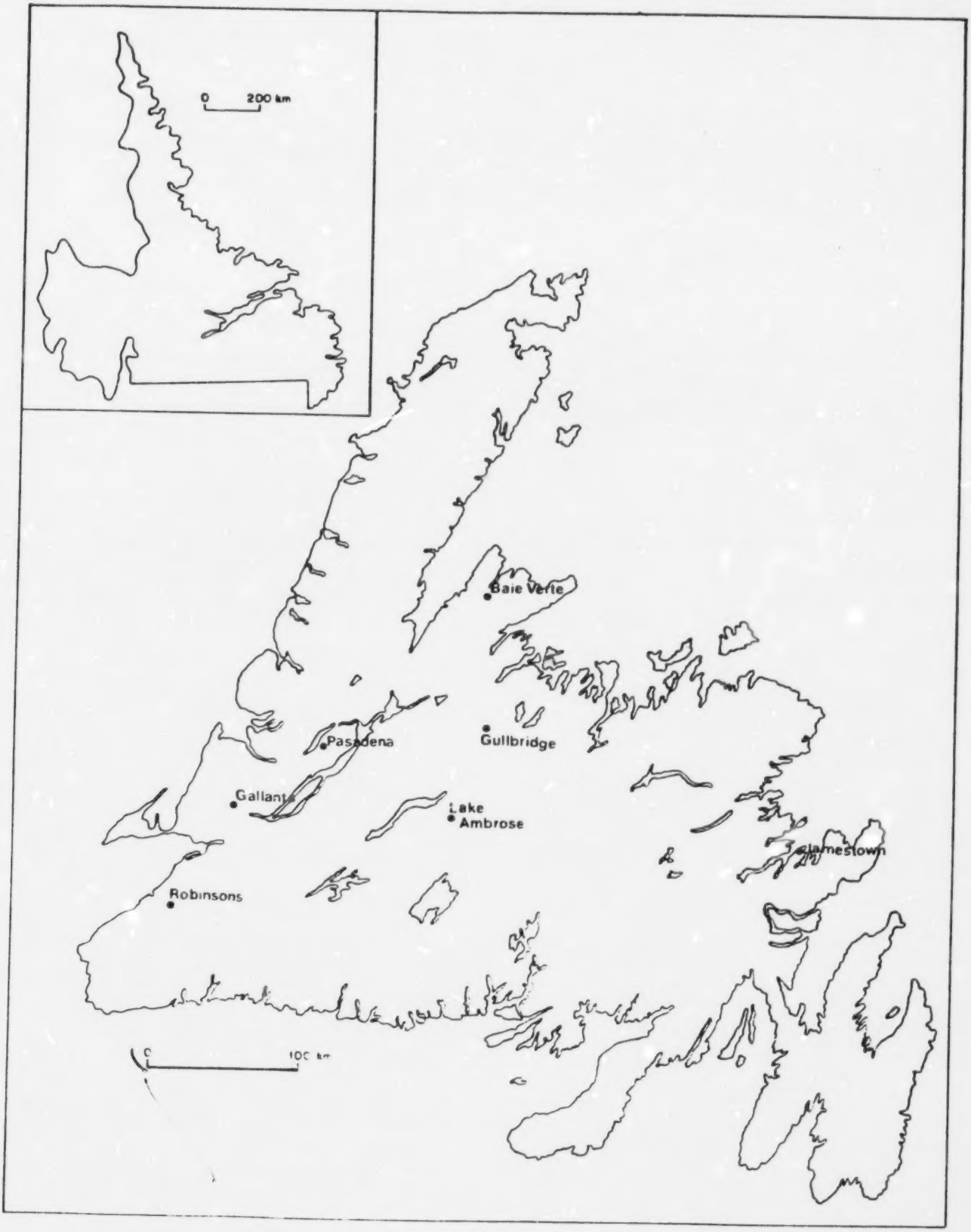

Fig. 1. Location of spruce budworm population dynamics research plots in Newfoundland - 1982.

Sampling Procedure

Four, circular, 100 m^2, fixed-radius (r = 5.64 m) plots were arbitrarily established in each stand. The plots were arranged in a square pattern (block) such that the distance between adjacent plot centres was 25 m. Two blocks of four plots each, however, were established in the same stand at Pasadena. Only in the stand at Gullbridge Mine Road were the plots established in an L-shaped pattern because of unusual terrain.

Ten trees were randomly selected and tagged within each circular plot. Trees with unusual crowns, dead or severely damaged trees were avoided. One, 45 cm branch tip was cut from the mid-crown region of each tree with a pole pruner. Branches were placed separately into a plastic bag and stored at 5½C until examination.

Stands were sampled on a weekly basis. Forty branches were collected from the tagged trees of each stand on each sampling occasion. The number of live and dead budworm in each developmental stage was recorded for each branch.

Laboratory Procedure for the Determination of Mortality Factors

A maximum of 100 budworm were randomly selected from the 40 branch tips collected on each sampling occasion to determine the incidence of mortality caused by parasites and/or various diseases. Where the number of budworm was less than 100, all were examined.

Live specimens were reared individually in 50 ml, clear, plastic cups containing about 10 ml of artificial diet (Bio. Serv., Frenchtown, N.J., U.S.A.). Larvae and pupae were then monitored for the presence of parasites or disease. Rearing environment was maintained at 21 ± 1°C, 60-80% R.H. and with a photoperiod of LD 16:8 h. Dead specimens were dissected and prepared for light microscopy to determine the cause of mortality.

RESULTS AND DISCUSSION

Location and Establishment of Research Plots

Preliminary sampling for overwintering, second instar, spruce budworm larvae indicated that population density gradually increased from eastern to western Newfoundland for all balsam fir stands sampled. Population density per branch tip ranged from 0.22 at Gambo and Lake Ambrose - A to 10.22 at Pasadena - A (Table 1). The mid-crown branch tip is a most suitable and practical sample unit (Sanders 1980). Populations on the branch tip only represent about a third of the total population of hibernating second instar larvae on the whole branch (Moody and Otvos 1980). Therefore, it is likely that the density of second instar larvae is underestimated. Our survey technique, however, does provide a rapid method with which to detect and compare the density of second instar larvae in balsam fir stands on a relative basis. These results were then used to determine the location of the research plots.

Table 1. Mean density of overwintering second instar spruce budworm, Choristoneura fumiferana (Clem.), larvae at various locations across insular Newfoundland sampled in April, 1982.

Region	Location	Mean number of 2nd instar larvae per 45 cm branch tip[1]
Western	Deer Lake	0.89
	Pasadena - A	10.22
	Pasadena - B	5.44
	Gallants - A	3.11
	Gallants - B	3.22
	Barry Brook	3.44
	Robinsons	4.22
Central	La Scie - A	1.22
	La Scie - B	0.78
	La Scie - C	0.44
	Baie Verte - A	0.67
	Baie Verte - B	0.56
	Gullbridge Mine Rd.	0.89
	Aspen Brook	0.33
	Lake Ambrose - A	0.22
	Lake Ambrose - B	0.67
Eastern	Jamestown - A	1.33
	Jamestown - B	3.11
	Adeytown	0.33
	Gambo	0.22
	Square Pond	0.38

[1]Sample unit is one, 45 cm mid-crown branch tip of balsam fir, Abies balsamea (L.) Mill. The sample size is nine (n = 9).

Population Levels

In general, population levels were low in all stands with less than five budworm per branch tip at the early larval stage (2nd to 4th instars). The population level was highest at Robinsons, but became progressively lower in stands located further east.

Population level appeared to increase in most stands from 7 June to 21 June (Table 2, Figs. 2 and 3). Generally, density of the spruce budworm is expected to decrease in some exponential manner as the insect progresses through each developmental stage (Morris and Miller 1954). The most plausible explanation for this apparent increase is that second instar larvae immigrated into the stands during the known redistribution of larvae that occurs in early spring (Kemp et al. 1980). At densities of less than one per branch tip at the early larval stage later developmental stages are virtually undetectable using the present sample size of 40 (Table 2).

Population dynamics statistics for early instar larvae, late instar larvae and pupae are summarized for each stand in Tables 3, 4 and 5, respectively. The sample frequency distributions from all stands for the early larval stage could be adequately described by the negative binomial distribution, but not by the Poisson. In general, the degree of aggregation, as indicated by the k values, increased as mean density decreased. The following linear regression was calculated for k as a function of mean density, m, for early instar larvae:

Table 2. Weekly mean density of spruce budworm, Choristoneura fumiferana (Clem.), in Newfoundland, 1982.

Week beginning	Stadium	Mean Density/45 cm Branch tip[1]						
		Robinsons	Gallants	Pasadena - A	Baie Verte	Gullbridge Mine Road	Lake Ambrose	Jamestown
7 June	L_2-L_4	2.80	1.12	1.95	0.58	0.05	0.08	0.15
14 June	L_2-L_4	-	-	1.00	-	-	-	-
21 June	L_4-L_5	4.42	2.20	2.03	0.13	0.35	0.50	0.05
28 June	L_5-L_6	4.25	2.53	2.73	0.28	0.10	0.13	0.35
5 July	L_5-L_6	3.83	1.63	2.90	0.55	0.03	0.08	0.52
12 July	L_6/Pupal	1.53/0.10	1.23/ -	2.13/ -	0.13/ -	0.05/ -	0.13/ -	0.13/ -
19 July	L_6/Pupal	0.53/0.78	0.15/0.18	2.23/0.13	0.25/0.03	-	-	0.15
26 July	L_6/Pupal	0.05/0.45	- /0.03	0.35/1.15	0.03/ -	0.03/ -	-	0.05/0.08
	Adult	0.13	-	0.05	-	-	-	-
2 Aug	Pupal	-	0.03	0.65	0.03	0.03	-	0.05
	Adult/Egg Mass	0.08/ -	0.03/ -	0.23/0.03	- / -	- / -	- / -	- / -
9 Aug	Pupal	-	-	0.05	0.03	-	-	-
	Adult/Egg Mass	0.25/ -	- / -	0.53/0.90	- / -	- / -	- / -	- / -

[1]The sample unit is one, first-order, mid-crown branch from balsam fir, Abies balsamea (L.) Mill. The sample size is 40 (n = 40).

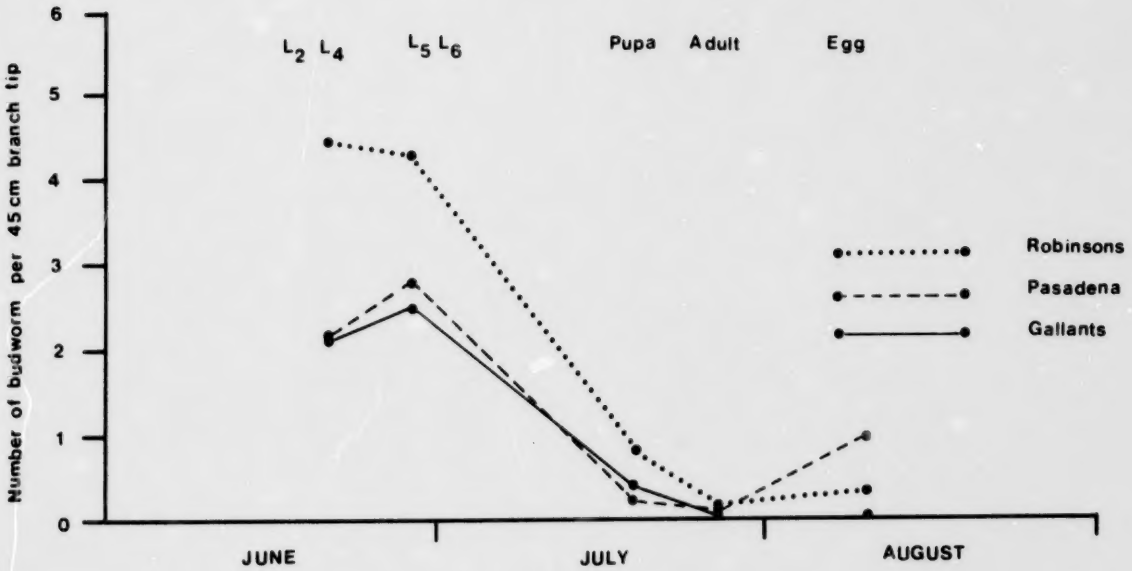

Figure 2. Seasonal population levels of spruce budworm in western Newfoundland, 1982.

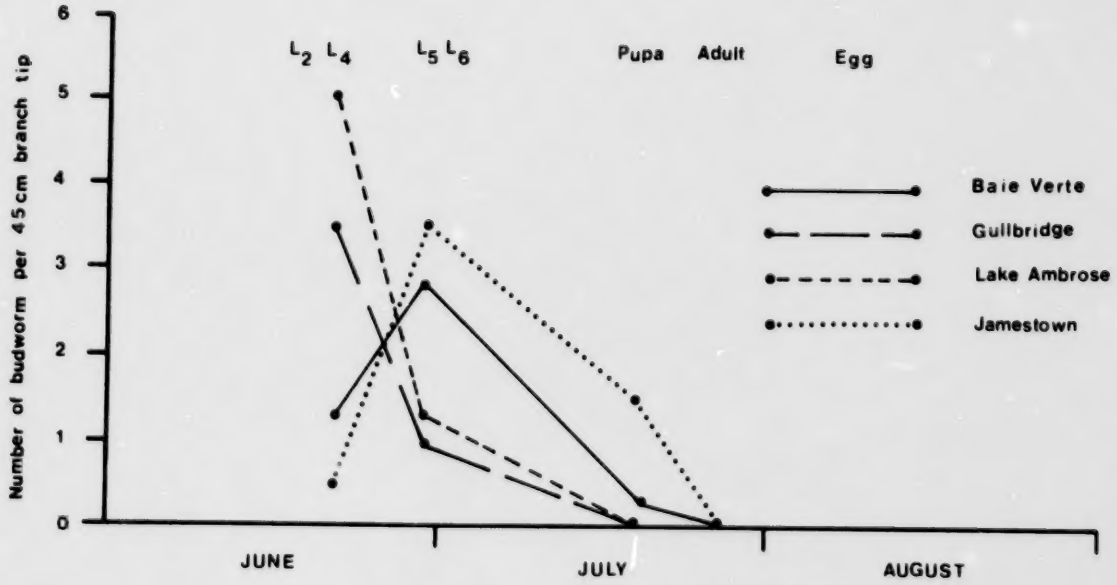

Figure 3. Seasonal population levels of spruce budworm in central and eastern Newfoundland, 1982.

Table 3. Population dynamics statistics for early instar larvae (2nd to 4th instars) of spruce budworm, Choristoneura fumiferana (Clem.), in Newfoundland, 1982.

Plot location	Sampling date	Mean density[1]	% Mortality Factors				Degree of aggregation[2] (k)
			Parasitism	Nosema	Fungi	Total mortality	
Robinsons	22 June	4.425	35.7	4.1	16.3	56.1	3.1748
Robinsons	30 June	4.250	33.0	2.0	25.0	60.0	1.8406
Gallants	23 June	2.200	5.7	2.3	20.5	28.5	1.6070
Gallants	29 June	2.525	8.2	4.1	12.2	24.5	1.2155
Pasadena - A	28 June	2.725	5.0	3.0	15.0	23.0	1.1469
Pasadena - B	5 July	2.900	8.0	-	8.0	16.0	1.3445
Pasadena - B	8 July	2.225	5.7	1.2	11.4	18.3	1.3735
Gullbridge Mine Rd.	22 June	0.350	7.1	-	-	7.1	0.2358
Baie Verte	30 June	0.275	9.1	-	-	9.1	0.2977
Lake Ambrose	22 June	0.500	20.0	-	20.0	40.0	0.1572
Jamestown	5 July	0.425	20.0	-	20.0	40.0	0.6115

[1]The sample unit is one, first order, 45 cm, mid-crown branch from balsam fir, Abies balsamea (L.) Mill. The sample size is 40 (n = 40).

[2]Based on maximum likelihood estimate of the negative binomial parameter k (Bliss and Fisher 1953).

Table 4. Population dynamics statistics for late instar larvae (5th to 6th instars) of spruce budworm, Choristoneura fumiferana (Clem.), in Newfoundland, 1982.

Plot location	Sampling date	Mean density[1]	% Mortality Factors				Degree of aggregation[2] (k)
			Para-sitism	Nosema	Fungi	Total mortality	
Robinsons	15 July	1.525	10.9	5.5	14.5	30.9	2.4614
Gallants	14 July	1.225	4.5	6.8	22.7	34.0	0.7727
Pasadena - A	13 July	2.125	9.8	-	6.1	15.9	1.3762
Pasadena - B	16 July	2.350	5.3	1.1	9.6	16.0	3.8842
Gullbridge Mine Rd.	13 July	0.050	-	-	-	-	-
Baie Verte	20 July	0.250	-	-	10.0	10.0	-
Lake Ambrose	13 July	0.125	-	-	100.0	100.0	-
Jamestown	20 July	0.150	-	-	50.0	50.0	-

[1]The sample unit is one, first-order, 45 cm, mid-crown branch from balsam fir, Abies balsamea (L.) Mill. The sample size is 40 (n = 40).

[2]Estimate of negative binomial parameter k (Bliss and Fisher 1953).

Table 5. Population dynamics statistics for pupae of spruce budworm, Choristoneura fumiferana (Clem.), in Newfoundland, 1982.

Plot location	Sampling date	Mean density[1]	% Mortality Factors				Degree of aggregation[2] (k)
			Parasitism	Nosema	Fungi	Total mortality	
Robinsons	21 July	0.780	9.7	-	-	9.7	-
Gallants	27 July	0.180	-	-	-	-	-
Pasadena - A	27 July	0.930	5.4	2.7	-	8.1	-
Pasadena - B	29 July	1.150	2.2	2.2	-	4.4	1.2763
Gullbridge Mine Rd.	10 Aug	0.025	-	-	-	-	-
Baie Verte	20 July	0.025	-	-	-	-	-
Jamestown	27 July	0.075	33.3	-	-	33.3	-

[1]The sample unit is one, first-order, 45 cm mid-crown branch, from balsam fir, Abies balsamea (L.) Mill. The sample size is 40 (n = 40).

[2]Estimate of negative binomial parameter k (Bliss and Fisher 1953).

(1) $k = 0.09 + 0.54\ m$

$r^2 = 0.76$

$n = 11$

$S_{y.x} = 0.45$

For late instar larvae, at mean densities less than 0.3 per branch tip, sample frequency distributions fit neither the Poisson distribution, nor the negative binomial distribution (Table 4). Only for stands located in the western part of the Island where density levels were higher did the sample frequency distributions conform to the negative binomial distribution which indicates the individuals in various populations are aggregated.

Mean densities for the pupal stage were generally too low to describe their spatial distributions (Table 5). For the stand at Pasadena - B, with a density of 1.15, the sample frequency distribution conformed to the negative binomial distribution. Sample frequency distributions from all other stands fit neither the Poisson nor the negative binomial distributions.

Egg mass sampling at all stands indicated low residual budworm populations (Table 6). Mean egg mass density per branch tip ranged from 0.025 to 1.575. No egg masses were found in stands located at Gullbridge Mine, Lake Ambrose or Jamestown. Low budworm populations are expected in all population dynamics research plots during 1983.

Mortality Factors

The most common parasites encountered were Apanteles fumiferanae Vier. and Glypta fumiferanae (Vier.). Most fungal diseases were attributed

Table 6. Mean egg mass density of spruce budworm, Choristoneura fumiferana (Clem.), in Newfoundland, 1982.

Plot location	Mean egg mass density per 45 cm branch tip[1]
Robinsons	0.025
Gallants	0.050
Pasadena - A	1.575
Gullbridge Mine Rd.	-
Baie Verte	0.025
Lake Ambrose	-
Jamestown	-

[1]The sample unit is one, first order, 45 cm, mid-crown branch from balsam fir, Abies balsamea (L.) Mill. The sample size is 40 (n = 40).

to Zoophthora radicans (Bref.) Batko. A microsporidian pathogen, Nosema fumiferanae (Thom.), was also frequently encountered in cadavers of all host life stages.

The degree of parasitism was particularly high at 33.0 to 35.7% in the stand at Robinsons during the early larval stage (Table 3). For samples from most other stands, the degree of parasitism was less than 10%. The presence of parasites could not be detected in samples from stands located east of Gullbridge Mine for the late larval stages. It is quite possible that budworm densities were too low during this period in these stands. In the western stands (west of Pasadena), where budworm densities were higher, the degree of parasitism ranged from 5.3 to 10.9% (Table 4). Pupal parasitism ranged from 2.2 to 9.7% in the western stands but reached 33% near Jamestown (Table 5).

The microsporidian, N. fumiferanae (Thom.), was present only in stands west of Pasadena. The incidence of this disease was comparatively low, ranging from 1.2 to 4.1% for early instar larvae (Table 3), 1.1 to 6.8% for late instar larvae (Table 4) and 2.2 to 2.7% for pupae (Table 5).

The incidence of fungal diseases ranged from 8.0 to 25.0% during the early larval stage (Table 3) and from 6.1 to 100.0% during the late larval stage (Table 4). No fungal disease was detected during the pupal stage.

It would appear that parasites and diseases were highly operative during the early larval stage of the host budworm population. In contrast, the incidence of the N. fumiferanae was lower, but occurred on larval and pupal stages of the host population.

ACKNOWLEDGEMENTS

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